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RESEARCH PAPER

Introduction of Raikhanim (*Ficus semicordata*) in a Maize and Finger-Millet Cropping System: An Agroforestry Intervention in Mid-Hill Environment of Nepal

Ram Pandit · Krishna Chandra Paudel

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Abstract Fodder trees are integral part of farming system in the hills of Nepal, but designed agroforestry interventions targeted to particular trees and crops are not widely available. This paper examines the joint productivity of an agroforestry practice in which Raikhanim (*Ficus semicordata*) is planted in a maize (*Zea mays*) and finger-millet (*Eleusine coracana*) cropping system at Keware Bhanjyang of the western mid-hills of Nepal. Raikhanim seedlings were planted in a row on terrace risers 2, 4 and 6 m apart in ordinary farming conditions, in a randomized block design with three replications. Maize and finger-millet were grown on the terraces as intercrops with a control plot without trees on risers in each replicate. Growth parameters of Raikhanim—height, diameter at 30 cm above ground (D_{30}) and survival rate—were recorded annually in December until trees were lopped for fodder biomass, and crop yields were measured to determine tree-crop interaction effects. Tree height and D_{30} differed significantly between spacings until trees reached the lopping stage 3½ years after planting, with the highest growth in 4 m spacing. Tree lopping checked the height growth but the diameter growth continued to increase and differed among spacings after lopping. Fodder biomass increased with tree age and was highest under 4 m spacing (7.294 t/ha) followed by 6 m (5.256 t/ha) and 2 m (3.84 t/ha). Finger-millet yield in the experimental plots decreased with tree age due to shading effects, while maize yield was not substantially affected. Among spacings, control plots produced the highest finger-millet yield (1,624 kg/ha) while the 6 m spacing produced the highest maize yield (2,463 kg/ha). It is concluded that planting Raikhanim at 6 m intervals will produce additional fodder without significant effect on maize yield and only a moderate

R. Pandit (✉)
School of Agricultural and Resource Economics, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
e-mail: ram.pandit@uwa.edu.au

K. C. Paudel
Ministry of Forest and Soil Conservation, Government of Nepal, Singhadurbar, Kathmandu, Nepal

effect on finger-millet yield. The agroforestry practice of planting fodder trees on under-utilised terrace risers is a viable option for mid-hill farmers for simultaneous production of fodder and cereal crops while sustaining the hill farming system.

Keywords Terrace riser · Fodder biomass · Farming system · Spacing regime

Introduction

Trees have been an integral part of subsistence farming in developing countries to add diversity to the farming system and to sustain rural household economies (Nair 1993; Arnold and Dewees 1997). Farming communities around the world have developed complex agroforestry practices to fulfill their household needs by combining trees, crops and livestock in their farming practices based on traditional knowledge and research findings (Thapa et al. 1995; Walker et al. 1995; Miller and Nair 2006). In the context of Nepalese hills, agroforestry practice has a special significance, because it has been an integral part of the farming system to sustain agricultural practices, to support livestock production, and to produce forest products for household consumption (Fonzen and Oberholzer 1985; Carter 1992; Amatya and Newman 1993; Garforth et al. 1999; Schmidt-Vogt 1999; Neupane et al. 2002). Its special significance in the hills is due to heavy reliance of farming households on tree resources, and the need to sustain farming and to generate environmental benefits (e.g. reduced soil erosion) from the same piece of land.

The complex topography (i.e. varying slope, elevation, aspects) of the hills creates a delicate situation between forest resources and farming practices. Wyatt-Smith (1982) found that every hectare of cultivated land in the hills needs 2.8 ha of unmanaged forest to provide sufficient fodder to livestock without damaging the forest condition. Among the cultivated area, *bari* land (rain-fed crop terraces) constitutes about 64 % (1.72 M ha) of the farm land in Nepal, most of which lies in the hills (Carson 1992). In the hill slopes, *bari* land is characterized by a step-like structure with short-width terraces and high and wide terrace risers, which constitute about one-third of the *bari* land (Barakoti 2007). Growing seasonal crops including maize and finger-millet on terraces and fodder trees on terrace risers is a traditional farming practice in the hills. However, due to increased need of fodder for livestock, decreased and deteriorated forest areas, and subsistence needs of households, a more efficient way to produce both crops and fodder from the same unit of *bari* land has been a necessary intervention to sustain farming practices (Abington 1992; Neupane and Thapa 2001).

One of the ways to sustain farming practice and to mitigate increased demand for fodder is to introduce appropriate fodder trees in existing cropping patterns. Evidence suggests that households in the mid-hills have been active in cultivating, protecting and utilizing trees on their land to increase tree cover and to produce additional fodder and fuelwood (Carter and Gilmour 1989; Gilmour 1997). However, given the need for simultaneous production of multiple products—for example food and fodder—from limited land, subsistence farmers face a challenge to find optimal tree-crop combinations even to introduce a single tree species into their existing cropping pattern. Farmers need scientific guidance on optimal spacing

regimes and shading effects of trees on crop yields, which is generally lacking in Nepal even for the dominant cropping pattern of maize and finger-millet and the popular Raikhanim fodder tree species. Even though Panday (1982) and Thapa et al. (1997) reported many families and species of fodder trees grown on *bari* land, no detailed information on likely shading effects of fodder trees on crop yields was identified. Therefore, this research was designed to examine optimal planting spacing to integrate Raikhanim in the existing maize and finger-millet cropping pattern for simultaneous production of fodder and cereal crops in the mid-hills *bari* land.

The Mid-hills Area and Study Site

The hilly region of Nepal occupies 63 % of the total land area (14.72 M ha) with about 42.2 % of the total agricultural land (2.50 M ha) and about 43 % of the total population (26.62 M) (CBS 2011). The agricultural landholdings in the hills are small and fragmented with an average holding area of 0.6 ha comprised of 2.9 parcels (CBS 2011). Two dominant land uses are prevalent in the hilly region due to its diverse geography, climate and altitudinal variations, these being rain-fed upland and irrigated bottom valleys, locally called *bari* and *khet* respectively.

The mid-hill region, which stretches between 1,000 and 2,000 m asl within the hilly region, occupies about 30 % of the land area of Nepal (Carson 1992). It extends from the southern slopes of the main Himalayan range in the north to the *Mahabharat* range in the south, with width varying from 60 to 110 km, and running from east to west (HMG/ADB/FINNIDA 1988). This region is heavily dominated by *bari* land for cultivation, with approximately 61 % of the cultivated *bari* land lying in the mid-hills region alone (Carson 1992). Maize is the major staple crop in the *bari* land and finger-millet is predominantly relay-intercropped under maize (Shrestha 1992).

This study was conducted at Keware Bhanjyang of Syangja district, a mid-hill village in western Nepal (Fig. 1). Keware Bhanjyang previously was one of the Off-Station Research Sites of Lumle Agricultural Research Centre representing the mid-hill environment that covers an altitude range of 900–1,500 m asl. A total of 497 farming households reside in this site, most of them having access to *bari* land, while only about 60 % of households (294) have access to *khet* land (Loader and Amartya 1999). Maize and finger-millet are the dominant summer crops cultivated by the farming households in the *bari* land. Maintaining traditionally grown fodder trees on terrace risers is also a common practice among farmers at this site to produce fodder for livestock as a means of subsistence farming.

Raikhanim is a medium sized fodder tree that grows in the hills up to 2,000 m asl and is lopped during winter (December–February) for fodder. It is the second most preferred fodder tree by farmers in the study site after Badahar (*Artocarpus lackoocha*), having rapid growth and producing nutritious fodder (Paudel and Tiwari 1992). A mature tree can reach a height of about 10 m (Manandhar and Manandhar 2002), and produce 8–18 kg of dry matter foliage (Jackson 1984), or 50–100 kg of fresh foliage (Panday 1982) in a season.

Fig. 1 Map of Nepal showing study district and research site

Research Method

An experiment was established in a farmer's *bari* land at Keware Bhanjyang (1,200 m asl) in July 1991, under a randomized block design with three replications, where 2 m wide and 15 m long terrace risers were considered as replicates. The experimental site was characterized by narrow bench terraces facing south with extended exposure to sun during winter and low soil moisture relative to north-facing *bari* land. Raikhanim seedlings were planted in pits (25 cm × 25 cm × 25 cm) in the middle portion of the risers at a spacing of 2, 4, and 6 m in a row whereas maize and finger-millet were grown on the terraces. Altogether 7, 4 and 3 Raikhanim trees were planted in 2, 4, and 6 m spacing regimes respectively. A control plot without trees on risers was maintained in each replicate. A 6 m × 1.5 m (9 m^2) sample plot was established at the middle portion of each terrace within each treatment regime to collect crop yield data. While the maize yield was recorded from the entire plot (9 m^2) in all treatments (2, 4, 6 m, and control without trees), the finger-millet yield was recorded from six sub-plots of 1 m × 1 m size within the 9 m^2 sample plot by leaving 0.25 cm border in both inner and outer sides of the plot.

The local varieties of maize (*Keware local yellow*) and finger-millet (*Okhle kodo*) were cultivated as relay-crops on the experimental plots. All cultural operations of maize and finger-millet including planting, fertility management and weed control were conducted according to local farming practices. The maize and finger-millet yields were recorded for the entire fodder lopping period from 1994 to 1997. However, finger-millet was not cultivated in 1994 and the missing values were estimated during data analysis using Genstat-12.

For Raikhanim, plant height, survival rate and diameter at 30 cm above ground (D_{30}) were recorded annually in December until fodder lopping commenced in winter 1994 (December–January). The yearly data on tree growth (height and D_{30}), survival, fodder biomass and crop yields were analyzed using two-way Analysis of Variance (ANOVA) considering replication as a blocking factor to examine the

effect of treatment regimes (spacings), year, and their interactions on fodder, maize and finger-millet yields. For tree height and diameter growth of Raikhanim, separate analyses were performed for two time periods based on the time of first lopping before 1991–1994 and after 1995–1997.

Results

Height, Diameter (D_{30}), and Survival of Raikhanim

Table 1 presents the results of separate analyses of height and diameter growth of Raikhanim among spacing regimes for before and after lopping. Prior to lopping the mean height of Raikhanim was significantly higher ($p \leq 0.05$) in 4 and 6 m spacings compared to that in 2 m spacing. The mean plant height gradually increased in the years before lopping, from 0.54 m in 1991 to 1.94 m in 1994. Among spacings, the least height growth across the years was in 2 m spacing (i.e. 0.65 m in 1992, 0.94 m in 1993, and 1.35 m in 1994). The mean diameter growth also increased over the years and across the treatments (spacings). But the diameter was significantly different only between spacings ($p \leq 0.05$), with lowest mean D_{30} in 2 m spacing for all years and highest in 6 m spacing in 1992 (0.51 cm) and 1993 (2.07 cm).

In the lopping period (1995–1997), the annual lopping practice effectively controlled the average height growth of Raikhanim trees resulting in similar height across all treatments (Table 1). The height growth was not statistically significant ($p \geq 0.05$) by both year and spacing regime. However, D_{30} continued to grow and was significantly different ($p \leq 0.05$) among spacings with the highest mean diameter growth in 4 m and lowest in 2 m spacing (Table 1). This diameter difference was attributed mainly to lopping and the spacing between Raikhanim trees in different spacing treatments. The spacing between the trees limited the number of trees in each plot (7 in 2 m, 4 in 4 m, and 3 in 6 m over 15 m long plots) and influenced the diameter growth through relative competition for water and

Table 1 Mean height (m) and D_{30} (cm) of planted Raikhanim on terrace risers before and after lopping at Keware Bhanjyang

Spacing regime	Before lopping (1991–1994)		After lopping (1995–1997)	
	Height	D_{30}	Height	D_{30}
2 m	0.91^{b}	1.22^{k}	3.00^{p}	4.37^{y}
4 m	1.18^{a}	2.01^{j}	3.44^{p}	7.72^{x}
6 m	1.18^{a}	2.07^{j}	2.86^{p}	6.91^{x}
SEd[1]	0.124	0.235	0.415	0.756

[1] Standard error of difference of means (SEd)

Superscripts a, b and j, k for height and D_{30} before lopping and p and x, y for height and D_{30} after lopping are used to compare mean differences respectively on means by spacing. Same superscript between two spacing means denotes no significant difference

nutrient resources between trees. The plant survival rate was about 95 % in 2 m and 100 % in both 4 and 6 m spacings until lopping commenced in winter 1994.

Fodder Biomass Production

After fodder harvest from Raikhanim trees commenced in 1994, all trees in each treatment (spacing) regime were lopped annually during December following farmers' practice. Table 2 summarizes the fodder yield by year and spacing regime, which increased significantly over the years ($p \leq 0.001$) and differed significantly between spacings ($p \leq 0.018$). Among years, the fodder yield was a minimum in 1994 and a maximum in 1997 (Table 1) indicating the increased fodder biomass production as tree grew. Among spacings, 4 m produced the maximum fodder biomass followed by 6 m with lowest in 2 m spacing (Table 2). However, no statistically significant interaction effect was present between spacing and year ($p \geq 0.894$, LSD = 4.642) on fodder yield during the study period.

Compared to the fodder biomass produced in 1997, the fodder yield in 1994 was only about 4, 11, and 8 % in 2, 4, and 6 m spacing respectively. Across the years, 4 m spacing produced the highest amount of fodder each year among three spacing regimes, with about 38 % and 24 % more fodder production than in 2 and 6 m spacing in 1997. This trend of fodder production signifies the importance of optimal planting spacing of Raikhanim trees. With only one additional Raikhanim tree at 4 m compared to 6 m spacing, the fodder production increased significantly in successive years.

Maize and Finger-Millet Yields

Raikhanim trees had no effect on maize and finger-millet yields until lopping commenced in 1994 when the average tree height and D_{30} of plants were about 1.94 m and 3.12 cm respectively. Once trees were first lopped, both maize and finger-millet yields differed significantly among treatment regimes ($p \leq 0.001$). Lopping of trees produced new shoots, which led to increase in fodder yield in the

Table 2 Mean fodder biomass from planted Raikhanim by treatment (spacing) and year at Keware Bhanjyang (t/ha)

Year	Treatment (spacing) regime (m)			Yearly mean
	2 m	4 m	6 m	
1994	0.29	1.44	0.81	0.85^{y}
1995	1.77	4.49	2.81	3.02^{y}
1996	5.29	10.38	7.58	7.75^{x}
1997	7.93	12.87	9.82	10.21^{x}
Spacing mean	3.82^{c}	7.29^{ab}	5.26^{bc}	5.46
SEd (LSD)		1.119 (2.32)		1.292 (2.68)

Figures in parentheses are least significant differences between means (LSD) at 5 % level

Superscripts a, b, c and x, y, z are used to compare mean differences respectively for spacing and yearly means. Same superscript between two means denotes no significant difference

subsequent years as tree canopy became wider through new leading branches. The wider tree canopies on risers cast wider and deeper shade on crops grown on terraces and reduced the crop yield.

Table 3 presents the maize yield by year and treatment, including control plots where no trees were planted on terrace risers. Maize yield was heavily influenced by spacing regime but did not differ significantly between years ($p \geq 0.124$). Similarly, no significant treatment and year interaction was found on maize yield ($p \geq 0.413$, LSD = 924). The maize yields in 2 and 4 m spacing plots were reduced significantly by about 43 and 38 % compared to control plot yield (Table 3, LSD = 469.2) suggesting that Raikhanim trees in plots with high density of trees created sufficient shade to reduce the maize yield. The yields in 6 m spacing plot were comparable to control plot yields in the later years (1996–1997), but higher in earlier 2 years (1994–1995). The 2 m spacing treatment produced the lowest maize yield in each year, which was related to the relatively large number of trees (7 trees) on risers in this treatment compared to fewer trees in 6 m spacing treatment (3 trees).

Table 4 presents the mean finger-millet yield by year and treatment at Keware Bhanjyang. ANOVA reveals a significant differences on mean yield by spacing ($p \leq 0.001$), year ($p \leq 0.001$), and spacing-year interaction ($p \leq 0.002$, LSD = 438.6). The mean finger-millet yield was always highest in control plots and significantly different from rest of the spacing treatments (Table 4). The lowest finger-millet yield was observed at 4 m spacing. In comparison to the control plot, mean finger-millet yields in 2, 4, and 6 m spacing were reduced by tree shade, being about 55, 59, and 36 % lower respectively.

The lowest finger-millet yield in 4 m spacing treatment coincides with the highest fodder biomass recorded in this treatment (Table 2). Finger-millet is susceptible to tree shade and heavier shade reduced its yield in this treatment. The relatively high number of trees (25 % more trees compared to 6 m spacing treatment) with highest mean diameter in this spacing treatment indicate superior growth and canopy coverage of Raikhanim trees that partly blocked the sunlight

Table 3 Mean maize yield by treatment and year at Keware Bhanjyang (kg/ha)

Year	Treatment				Yearly mean
	2 m spacing	4 m spacing	6 m spacing	control plot (without trees on risers)	
1994	1,298	1,114	2,522	1,402	1,594
1995	881	1,041	2,781	1,807	1,640
1996	1,037	1,196	2,100	2,192	1,641
1997	1,444	1,674	2,455	2,722	2,082
Spacing mean	1,162^{b}	1,259^{b}	2,463^{a}	2,044^{a}	1,737
SEd (LSD)		229.4 (469.2)			

The figure in parenthesis is the least significant difference of means at the 5 % level

Superscripts a, b, c and x, y, z are used to compare mean differences respectively for spacing and yearly means. Same superscript between two means denotes no significant difference

Table 4 Mean finger-millet yield by treatment and year at Keware Bhanjyang (kg/ha)

Year	Treatment				Yearly mean
	2 m spacing	4 m spacing	6 m spacing	Control plot (without trees on risers)	
1994	775	693	1,718	2,276	1,330^{x}
1995	928	892	1,450	2,427	1,424^{x}
1996	356	361	436	645	435^{y}
1997	964	780	1,002	1,150	967^{z}
Spacing mean	731^{c}	652^{c}	1,038^{b}	1,624^{a}	996
SEd (LSD)		117.3 (243.9)			

The figure in parenthesis is the least significant difference of means at the 5 % level

Superscripts a, b, c and x, y, z are used to compare mean differences respectively for spacing and yearly means. Same superscript between two means denotes no significant difference

needed for finger-millet and reduced its yield. Similarly, the yearly effect of treatments on mean finger-millet yield differed significantly, with highest yield in 1995 and lowest in 1996 (Table 4). The lowest yield of finger-millet in 1996 across the treatments was due to limited rainfall during late summer, with inadequate soil moisture on south-sloping *bari* land for the subsequent crop. Unlike north-facing *bari* land, southerly slopes are exposed to sun throughout the day and become drier in late-summer and winter, which was reflected in experimental plot yields of finger-millet in this study.

Discussion

Even though both 4 and 6 m spacing treatments produced higher maize and finger-millet yields than the 2 m spacing, a trade-off was found for fodder yield and crop yield between these two treatments. The trade-off largely depends on farmer's need for fodder and willingness to compromise crop yield in favour of fodder biomass. With increased restrictions on public land for grazing and need of nutritious fodder for livestock, 4 m spacing could be a viable option for farmers if fodder production is their priority. However, in the context of mid-hills where maintaining the various component of the farming system (crop-livestock-forest) is essential, planting Raikhanim trees 6 m apart on terrace risers appears to be the best option for farmers who aim to produce both fodder and crops from the same unit of *bari* land by utilizing unused terrace risers.

A comparison of the findings with previous studies is limited by scarcity of tree-crop interaction trials focused on the mid-hill environment in Nepal. A study from the eastern mid-hill at Belhara, Pakharibas found that planting Raikhanim on terrace ridges at 1.5 m apart along with three forage crops—broom grass (*Thysalonaema maxima*), Napier grass (*Pennisetum purpureum*) and Dhus (*Pennisetum* spp.)—on terrace risers reduced maize yield substantially compared to eight other tree-forage combinations (Barakoti 2007). Another study in the eastern hills reported by

Fretwell (1998) suggested that the estimated yield loss attributable to trees on terrace risers varies from 30 to 70 % depending on tree density and terrace size. From a study in Dolakha district of central mid-hills, Carter (1992) reported that the choice of fodder tree species and planting locations in the private farmland is based on farmers' views of the potential effect of tree shade on crop yields, highlighting the fact that farmers make a trade-offs between fodder tree types and planting locations. For planting locations, Paudel and Tiwari (1992) and Amatya and Newman (1993) suggested that planting trees on terrace risers of the *bari* land has a relatively small impact on crop yields in the hills.

The optimal use of terrace risers for additional fodder production is crucial because farming households are facing regulated access to nearby forests for fodder collection due to widespread practice of community forestry in the hills. As access to forest resources has declined over recent decades in the hills, the number of fodder trees on farms has increased to maintain a supply of vital winter (dry season) fodder to sustain animal populations (Carter and Gilmour 1989). In a recent survey of 259 households from six community forests of the Dolakha, Kavre and Nuwakot hill districts, Dhakal et al. (2011) found that the focus of community forestry policy on environmental protection has resulted in a substantial reduction in livestock holdings per household. They reported that compared to before commencement of community forestry practice, the average number of goats, cattle and buffaloes declined by 4.48–2.97 (34 %), 2.41–1.69 (30 %) and 1.45–1.05 (27 %) per household respectively, adversely affecting the hill farming system. These earlier findings signify the importance of introducing fodder trees on private land to support the hill farming system that closely integrates crop, livestock and forestry components.

Conclusion

This study examined an agroforestry practice of planting Raikhanim on terrace risers at three different spacings (2, 4 and 6 m) and its effect on maize and finger-millet yields in the mid-hill context of Nepal. Among three spacings, the results suggest that 2 m spacing generally produces lowest maize and fodder yields, while 4 m spacing produces the greatest amount of fodder but reduces maize and finger-millet yields. Planting Raikhanim on terrace risers at 6 m spacing appears to be an appropriate agroforestry intervention for farmers who want to produce fodder and grain (maize and finger-millet) from the same unit of land by utilising otherwise unused terrace risers. Compared to the control plot yields of only maize and finger-millet, the trees at 6 m spacing produce additional fodder without substantial reduction in maize yield and with only moderate reduction in finger-millet yield. The introduction of Raikhanim in a maize and finger-millet cropping system would be beneficial for subsistence farmers in the mid-hills who have scarce land for production of fodder and crops.

An important implication of the findings is that fodder trees including Raikhanim should be introduced into the cropping system characterized by exposed and low quality terraces with wide risers, where trees can help to retain moisture for field crops during the dry period of the year. This type of agroforestry interventions can

improve soil fertility on the farms, reduce soil erosion from open risers and produce additional fodder and firewood to sustain hill farming. Additionally, it reduces the fodder shortages during winter by reducing pressure on forests and marginal land for fodder, and maintains livestock's contribution to the hill farming system.

Based on this study, it can be argued that integrating Raikhanim trees in the maize and finger-millet cropping pattern in the mid-hills *bari* land will contribute towards keeping three components of the hill farming system—crops, livestock, and forestry—in harmony, in the long run. Therefore, government policies in the hills should promote planting fodder trees at optimal spacing in private *bari* land to generate economic benefits to farmers vis-a-vis environmental benefits to society.

Due to the dearth of research, further studies are needed on the benefits generated by integrating fodder trees into existing cropping systems, tree-crop interactions with a focus on types of fodder trees, spacing regimes and cropping systems in the Nepalese context. Such trials would require control for other variables, such as aspect, rainfall and soil moisture, to identify best agroforestry practices for specific farm situations in the mid-hills.

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References

Abington J (ed) (1992) Sustainable livestock production in the mountain agro-ecosystem of Nepal. Animal Production and Health Paper 105. Food and Agriculture Organization, Rome

Amatya SM, Newman SM (1993) Agroforestry in Nepal: research and practice. Agrofor Syst 21(3):215–222

Arnold JEM, Dewees PA (eds) (1997) Farms, trees and farmers: responses to agricultural intensification. Earthscan, London

Barakoti TP (2007) Cultivation of fodder in terrace riser: a new model of agrisilvopastoral system in Nepal. Asia Pac Agrofor Newslett 29:4–6. Available at http://www.fao.org/docrep/012/al329e/al329e00.pdf. Accessed 21 Nov 2011

Carson B (1992) The land, the farmer and the future: a soil management strategy for Nepal. Occasional Paper No. 21. ICIMOD, Kathmandu

Carter EJ (1992) Tree cultivation on private land in the Middle Hills of Nepal: lessons from some villagers of Dolakha district. Mt Res Dev 12(3):241–255

Carter AS, Gilmour DA (1989) Increase in tree cover on private farm land in central Nepal. Mt Res Dev 9(4):381–391

CBS (2011) Nepal living standards survey 2010/11. Statistical report, vol 2. Central Bureau of Statistics, Kathmandu

Dhakal B, Bigsby H, Cullen R (2011) Forests for food security and livelihood sustainability: Policy problems and opportunities for small farmers in Nepal. J Sustain Agric 35(1):86–115

Fonzen PF, Oberholzer E (1985) Use of multipurpose trees in hill farming systems in Western Nepal. Agrofor Syst 2(3):187–197

Fretwell T (1998) Farmer knowledge about maize cultivation in the eastern mid-hills of Nepal. MSc thesis, School of Agricultural and Forest Sciences, University of Wales, Bangor

Garforth CJ, Malla YB, Neopane RP, Pandit BH (1999) Socioeconomic factors and agro-forestry improvements in the hills of Nepal. Mt Res Dev 19(3):273–278

Gilmour D (1997) Rearranging trees in the landscape in the Middle Hills of Nepal. In: Arnold J, Dewees P (eds) Farms, trees and farmers: responses to agricultural intensification. Earthscan, London, pp 21–42

HMG/ADB/FINNIDA (1988) Master plan for the forestry sector Nepal: main report Kathmandu, Nepal

Jackson JK (1984) Manual of afforestation in Nepal. Forest Research and Survey Centre, Babarmahal

Loader R, Amartya L (1999) Participatory rural appraisal: extending the research methods base. Agric Syst 62(2):73–85

Manandhar NP, Manandhar S (2002) Plants and people of Nepal. Timber Press Inc, Portland

Miller RP, Nair PKR (2006) Indigenous agroforestry systems in Amazonia: from prehistory to today. Agrofor Syst 66(2):151–164

Nair PKR (1993) State-of-the-art of agroforestry research and education. Agrofor Syst 23(2–3):95–119

Neupane RP, Thapa GB (2001) Impact of agroforestry intervention on farm income under the subsistence farming system of the middle hills, Nepal. Agrofor Syst 53(1):31–37

Neupane RP, Sharma KR, Thapa GB (2002) Adoption of agroforestry in the hills of Nepal: a logistic regression analysis. Agric Syst 72(3):177–196

Panday KK (1982) Fodder trees and tree fodder of Nepal. Sahayogi Prakashan, Kathmandu

Paudel K, Tiwari B (1992) Fodder and forage production. In: Abington J (ed) Sustainable livestock production in the mountain agro-ecosystem of Nepal. FAO Animal production and health paper (FAO) 105. FAO, pp 131–154

Schmidt-Vogt D (1999) Traditional agroforestry systems in Nepal. Erde 130(3–4):315–330

Shrestha R (1992) Agroecosystem of the mid-hills. In: Abington J (ed) Sustainable livestock production in the mountain agro-ecosystem of Nepal. Animal Production and Health Paper 105. FAO Rome, pp 7–26

Thapa B, Sinclair FL, Walker DH (1995) Incorporation of indigenous knowledge and perspectives in agroforestry development. Part 2: case-study on the impact of explicit representation of farmers' knowledge. Agrofor Syst 30(1–2):249–261

Thapa B, Walker DH, Sinclair FL (1997) Indigenous knowledge of the feeding value of tree fodder. Anim Feed Sci Technol 67(2–3):97–114

Walker DH, Sinclair FL, Thapa B (1995) Incorporation of indigenous knowledge and perspectives in agroforestry development. Part 1: review of methods and their application. Agrofor Syst 30(1–2):235–248

Wyatt-Smith J (1982) The agricultural system in the hills of Nepal: the ratio of agricultural to forest land and the problem of animal fodder. Occasional paper 1, vol 1. APROSC, Kathamndu